SECTION 8 - METALS (ALUMINUM)

SUMMARY

As a result of the 1998-1999 SWQB/NMED monitoring effort in the Jemez River Basin, several exceedances of New Mexico water quality standards for metals (chronic aluminum) were documented on both the Jemez River and the Rio Guadalupe. Figures 5.E.1 and 5.E.2 in Section 5 show the land use/cover and land ownership percentages for the segment of the Jemez River listed for this constituent (the Jemez River from Rio Guadalupe to the East Fork of the Jemez River). Figures 5.J.1 and 5.J.2, also in Section 5, show the land use/cover and land ownership percentages for the segment of the Rio Guadalupe also listed in the 2000-2002 §303(d) list for aluminum (the Rio Guadalupe from the Jemez River to the confluence with the Rio Cebolla and the Rio de las Vacas). Detailed descriptions of these two segments can be found in Subsections E and J of Section 5 of this document.

Photo 19. The Rio Guadalupe (looking upstream) at the confluence with the Jemez River

Photo 20. The Jemez River (looking upstream) at the confluence with the Rio Guadalupe

ENDPOINT IDENTIFICATION

Target Loading Capacity

Overall, the target values for this TMDL will be determined based on 1) the presence of numeric criteria, 2) the degree of experience in applying the indicator, and 3) the ability to easily monitor and produce quantifiable and reproducible results. For this TMDL document target values for metals are based on numeric criteria. This TMDL is consistent with the State's antidegradation policy.

Metals (chronic aluminum)
According to the New Mexico water quality standards (20.6.4.12 NMAC) the State's standards leading to an assessment of use impairment are the numeric criteria stating that "dissolved aluminum shall not exceed 87 µg/L," and "acute dissolved aluminum shall not exceed 750 µg/L" for the appropriate designated use of a fishery.

Although there are no adverse effects to biota at acute levels of 750 µg/L or chronic levels of 87 µg/L, high chronic levels of dissolved aluminum are toxic to fish, benthic invertebrates, and some single-celled plants. Aluminum concentrations from 100 to 300 µg/L increase mortality, retard growth, gonadal development and egg production of fish (http://h2osparc.wq.ncsu.edu).

To be conservative, these TMDLs were drafted for chronic aluminum, which should also protect against any acute exceedances.

Chronic Aluminum (Dissolved)
Aluminum is the most common metal in the Earth's crust and the third most common element. Aluminum comprises, on average, about eight percent of the Earth's crust (Moore, 1990). In addition, the volcanic rocks of the Jemez Mountains are particularly rich in aluminum (SWQB/NMED, 2001). Rhyolite, one of the most common rocks in the Jemez Mountains, contains roughly 14 percent aluminum oxide (Al_2O^3) (Travis, 1955). Andesite, another common rock in the Jemez area, is comprised of 17 percent aluminum oxide. Basalt yields 16.8 percent aluminum oxide and the Bandelier tuff averages about 23.6 percent. Overall, the volcanic rocks of the Jemez Mountains have been determined to contain 14.5 percent aluminum oxide, nearly twice the average crustal abundance.

Normal aqueous chemical processes, enhanced by the slight natural acidity of snow and rain, are fully capable of rendering some of this abundant, naturally occurring aluminum available to the river system. The particularly high dissolved aluminum concentrations seen during the Spring sampling effort, up to 1,300 μg/L (ppb) as opposed to the 150 μg/L and 120 μg/L for Summer and Fall, respectively, are also indicative of a landscape source. Acidic anions as well as carbonic acid carried in snow are released into the soil as the snow melts and brings aluminum species into solution. Thus, aluminum concentrations are high during Spring runoff, despite the ordinarily diluting effects of high flow, and subsequently decline as the landscape dries out.

Flow
These TMDLs are calculated for the Jemez River and Rio Guadalupe at specific flows. Metal concentrations in a stream vary as a function of flow. As flow increases the concentration of metals can increase. When available, US Geologic Survey gages are used to estimate flow. In this case the gage for the Jemez River (USGS 08324000) is used. Flows recorded at this gage station are presented graphically for the entire sampling year (March 1998 to April 1999) in Figure 2, Section 4 of this document.

The gage for the Rio Guadalupe (USGS 08323000) is located at the downstream end of Guadalupe Box Canyon, 4.8 miles upstream from the mouth, 5 miles southwest of Jemez Springs, and 7 miles north of Jemez Pueblo (USGS, 1989). Where gages are absent, geomorphological cross sectional information is taken at each site and the flows are modeled.

It is important to remember that the TMDL is a planning tool to be used to achieve water quality standards. Since flows vary throughout the year in these systems the target load will vary based on the changing flow. Management of the load to improve stream water quality should be a goal to be attained. Meeting the calculated target load may be a difficult objective.

Calculations
A target load for metals (chronic aluminum) is calculated based on a flow, the current water quality standards, and a unit-less conversion factor, 8.34, that is a used to convert mg/L units to lb/day (see Appendix A for Conversion Factor Derivation). The target loads (TMDLs) predicted to attain standards were calculated using Equation 1 and are shown in Table 8-1.

Equation 1.

Critical Flow (MGD) x Standard (mg/L) x 8.34 (conversion factor) = Target Loading Capacity

Table 8-1: Calculation of Target Loads

Location	Flow (MGD)	Standard for Metals (Chronic Aluminum) (mg/L)	***Conversion Factor	Target Load Capacity (lb/day)
Jemez River	* 151	0.087	8.34	109.6
Rio Guadalupe	** 117	0.087	8.34	84.9

* Flow is the greatest monthly mean flow from 1936-1989 measured at USGS Gage 08324000 (USGS 1989)
**Flow is the greatest monthly mean flow from 1936-1989 measured at USGS Gage 08323000 (USGS1989)
***Conversion Factor used to convert mg/L to lb/day (See Appendix A)

The measured loads were similarly calculated. In order to achieve comparability between the target and measured loads, the flows used were the same for both calculations. The geometric mean of the data that exceeded the standards from the data collected at each site was substituted for the standard in Equation 1. The data collected from stations are located in Table 8-6 at the end of this section. The same conversion factor of 8.34 was used. Results are presented in Table 8-2.

Table 8-2: Calculation of Measured Loads

Location	Flow (MGD)	✧Field Measurements (mg/L)	***Conversion Factor	Measured Load (lb/day)
Jemez River	* 151	0.836	8.34	1052.8
Rio Guadalupe	** 117	0.256	8.34	250.0

* Flow is the greatest monthly mean flow from 1936-1989 measured at USGS Gage 08324000 (USGS 1989)
**Flow is the greatest monthly mean flow from 1936-1989 measured at USGS Gage 08323000 (USGS1989)
✧ Field Measurements are the geometric mean of the values that exceeded the standard (See Table 8-6)
***Conversion Factor used to convert mg/L to lb/day (See Appendix A)

Background loads were not possible to calculate in this watershed. A reference reach, having similar stream channel morphology and flow, was not found. It is assumed that a portion of the load allocation is made up of natural background loads. In future water quality surveys, finding a suitable reference reach will be a priority.

Waste Load Allocations and Load Allocations

•Waste Load Allocation
There are no point source contributions associated with this TMDL. The waste load allocation is zero.

•Load Allocation
In order to calculate the Load Allocation (LA), the waste load allocation and margin of safety (MOS) were subtracted from the target capacity (TMDL) using the following Equation 2.

Equation 2. $WLA + LA + MOS = TMDL$

Results using a Margin of Safety (MOS) of 15% (explained further in this section) are presented in Table 8-3.

Table 8-3: Calculation of TMDL for Metals (Chronic Aluminum)

Location	WLA (lb/day)	LA (lb/day)	MOS (15%) (lb/day)	TMDL (lb/day)
Jemez River	0	93.2	16.4	109.6
Rio Guadalupe	0	72.2	12.7	84.9

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the load allocation (Table 8-3) and the measured load (Table 8-2), and are shown in Table 8-4. For example, on the Jemez River, achieving the target load of 109.6 lb/day would require a load reduction of 959.6 lb/day.

Table 8-4: Calculation of Load Reductions (in lb/day)

Location	Load Allocation (lb/day)	Measured Load (lb/day)	Load Reduction (lb/day)
Jemez River	93.2	1052.8	959.6
Rio Guadalupe	72.2	250.0	177.8

Identification and Description of Pollutant Source(s)

Pollutant sources that could contribute to both segments are listed in Table 8-5.

Table 8-5: Pollutant Source Summary

Pollutant Sources	Magnitude (WLA+LA+MOS) (lb/day)	Location	Potential Sources (apply to both segments) (% from each)
Point: None	0	--------	0%
Nonpoint: Metals (chronic aluminum)	 109.6 84.9	 Jemez River Rio Guadalupe	100% Natural and Unknown

LINK BETWEEN WATER QUALITY AND POLLUTANT SOURCES

Metals such as aluminum, lead, copper, iron, zinc and others can occur naturally in watersheds in amounts ranging from trace to highly mineralized deposits. Some metals are essential to life at low concentrations but are toxic at higher concentrations. Metals such as cadmium, lead, mercury, nickel, and beryllium represent known hazards to human health. The metals are continually released into the aquatic environment through natural processes, including weathering of rocks, landscape erosion, geothermal or volcanic activity. The metals may be introduced into a waterway via headcuts, gullies or roads.

Depending on the characteristics of the metal, it can be dissolved in water, deposited in the sediments or both. Metals become dissolved metals in water as a function of the pH of a water system. In urban settings, stormwater runoff can increase the mobilization of many metals into streams.

Aluminum is naturally occurring in soils, clay, and rock. Substantial amounts are found in silicate igneous rock minerals and micas (USGS, 1986). Because of its amphoteric nature, meaning having the characteristics of both an acid and a base and capable of reacting as either, Al is more soluble in acidic and basic solutions than in circumneutral solutions. A decrease in pH due to the slight acidity of rain and snowmelt, coupled with high runoff rates due to riparian disturbance would result in higher chronic or acute levels of dissolved aluminum.

Examples of sources that can cause metals contamination:

- Activities such as resource extraction, recreation, some agricultural activities and erosion can contribute to nonpoint source pollution of surface water by metals.
- Stormwater runoff in industrial areas may have elevated metals in both sediments and the water column.

Where available data are incomplete or where the level of uncertainty in the characterization of sources is large, the recommended approach to TMDL assignments requires the development of allocations based on estimates utilizing the best available information.

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED, 1999). The Pollutant Source(s) Documentation Protocol, shown as Appendix B, provides an approach for a visual analysis of the source along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of potential sources of impairment in this watershed. Table 8-5 (Pollutant Source Summary) identifies and quantifies potential sources of nonpoint source impairments along each reach as determined by field reconnaissance and assessment. A further explanation of the sources follows.

Identification and Description of Pollutant Source(s) on the Jemez River and Rio Guadalupe

The Jemez River is formed by the confluence of the East Fork of the Jemez River and San Antonio Creek. Both streams are impaired due to turbidity. It is possible that this Jemez River segment is impaired due in part to upstream influences, since metals are often associated with sediment loads in streams. The primary sources of impairment along these reaches as listed in the State of New Mexico 2000-2002 §303(d) List for Assessed Stream and River Reaches are natural and unknown.

The natural sources of aluminum in the Jemez River are the predominant minerals composing the earth's crust. Aluminum in these minerals is mobilized naturally by percolating water and by surface runoff. The slightly acidic nature of rain and snow (and the increased solubility of aluminum at lower pH), the residence time of frozen or melting snow on the weathered portion of aluminum bearing minerals, and the acidic pulse that can occur with the first spring snowmelt are frequently observed to result in the highest concentrations of dissolved metals from a given area.

Photo 21. Jemez River (looking downstream) at Battleship Rock

Along both the Jemez River and the Rio Guadalupe, aluminum levels were found to be highest during the Spring sampling run. The particularly high dissolved aluminum concentrations seen during Spring sampling can be partially attributed to the aluminum being deposited in the soil from the snowmelt and the Spring runoff then converting it to dissolved form.

MARGIN OF SAFETY (MOS)

TMDLs should reflect a margin of safety based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. For this TMDL, there will be no margin of safety for point sources, since there are none. However, for the nonpoint sources the margin of safety is estimated to be an addition of 15% for metals to the TMDLs, excluding background. This margin of safety incorporates several factors:

•*Errors in calculating NPS loads*

A level of uncertainty exists in sampling nonpoint sources of pollution. Techniques used for measuring metals concentrations in stream water are $\underline{+}$15% accurate. Accordingly, a conservative margin of safety for metals increases the TMDL by 15%.

•*Errors in calculating flow*

Flow estimates were based on USGS gages. Conservative values were used to calculate loads and do not warrant additional MOS.

CONSIDERATION OF SEASONAL VARIATION

Data used in the calculation of this TMDL were collected during the Spring, Summer, and Fall (1998) in order to ensure coverage of any potential seasonal variation in the system. Critical condition is set to the highest flows for metals. Data where exceedances were seen (primarily during high Spring flows) were used in the calculation of the measured loads. The data and calculations for this TMDL are in Table 8-6 on the following page.

FUTURE GROWTH

Estimations of future growth are not anticipated to lead to a significant increase for metals (chronic aluminum) that cannot be controlled with best management practice implementation in this watershed.

TABLE 8-6: ALUMINUM RESULTS DURING 1998 SAMPLING EFFORT

All data in µg/L units

	SAMPLING STATION AND LOCATION			
	Station 1	**Station 3**	**Station 7**	**Station 13**
SAMPLING DATE	**Jemez River below Vallecito Creek**	**Jemez River above confluence with Rio Guadalupe**	**Jemez River below Battleship Rock**	**Rio Guadalupe above confluence with Jemez River**
4/20/1998	* 400	* 800	* 1200	* 310
4/21/1998	* 330	* 730	* 1200	* 280
4/22/1998	* 450	* 1000	* 1300	* 290
4/23/1998	* 300	no data	* 700	* 170
7/13/1998	< 10	40	* 100	< 10
7/14/1998	10	< 10	* 150	40
11/2/1998	50	70	* 120	no data
GEOMETRIC MEAN OF EXCEEDANCES --->	365.4 Dissolved (µg/L)	**** 835.9 Dissolved (µg/L)**	421.4 Dissolved (µg/L)	**255.8 Dissolved (µg/L)**

* Exceedance

** Geometric mean of exceedances from this station (Station 3) on Jemez River was used in the TMDL calculations (highest exceedances and closest to flow gage).